PAP-910

Tongue and Yellowstone Rivers Diversion Dam Fishway Feasibility Study

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Tongue and Yellowstone Rivers Diversion Dam Fishway Feasibility Study

Submitted to:
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TONGUE AND YELLOWSTONE RIVERS DIVERSION DAM FISHWAY FEASIBILITY STUDY

STUDY OBJECTIVE

The Montana Area Office (MTAO) requested the Water Resources Research Laboratory (WRRL), Denver, Colorado conduct a study to investigate improving fish passage at Tongue and Yellowstone Rivers Diversion Dam (T&Y Dam). The dam is a barrier to upstream passage of native fish species of the Tongue River and several species that migrate from the Yellowstone River into the Tongue River to spawn or forage. Fish passage for sauger and sturgeon are the primary objective of the project.

BACKGROUND

T&Y Dam is located on Tongue River about 12 river miles upstream of the confluence with the Yellowstone River, Figure 1. The dam provides about 11.5 ft of hydraulic head to divert water from Tongue River into the T&Y canal. The dam is composed of a concrete shell overlying a timber crib core. There are no outlets or sluices on the dam. The upstream riverbed is silted to near the dam crest. The T&Y canal headworks is located on the right bank about 50 ft upstream of the dam crest.

In 1998 the headworks of the T&Y Canal was rehabilitated and a fish protection louver added, Figure 2. The louver guides fish entrained at the canal headworks to a fish bypass channel that reenters the river below the dam. The louver now protects most fish larger than 200 mm in length from being entrained in the canal. Adding fish passage at the dam would allow fish to move past the dam to spawn or utilize upstream habitat and return downstream of the dam protected against entrainment into the canal.

The lower Tongue River is an important spawning area for sauger and shovelnose sturgeon and may be used by endangered pallid during periods of high runoff, (Backes, 1993). Sauger are found moving out of the Yellowstone River and into the Tongue from March to June. Spawning generally occurs in areas with gravelly or rocky substrate when water temperatures reach 4.4-10.0°C (40-50°F). The spawning migration for shovelnose sturgeon begins around the first of May with spawning occurring from early June until mid-July.

The fishery habitat exclusion currently imposed by T&Y Diversion Dam is illustrated in the findings of the Yellowstone Impact Study (Elser et al, 1977). The study lists 31 species of native and exotic fish found in the Tongue River. Of the 31 species, seven species were found solely in the river reach below the T&Y dam. These species were; Goldeye, Burbot, Walleye, Paddlefish, Shovelnose sturgeon, Blue sucker, and Sturgeon chub. The study also found population densities below the T&Y dam are much higher than upstream for many other native species like the Sauger.

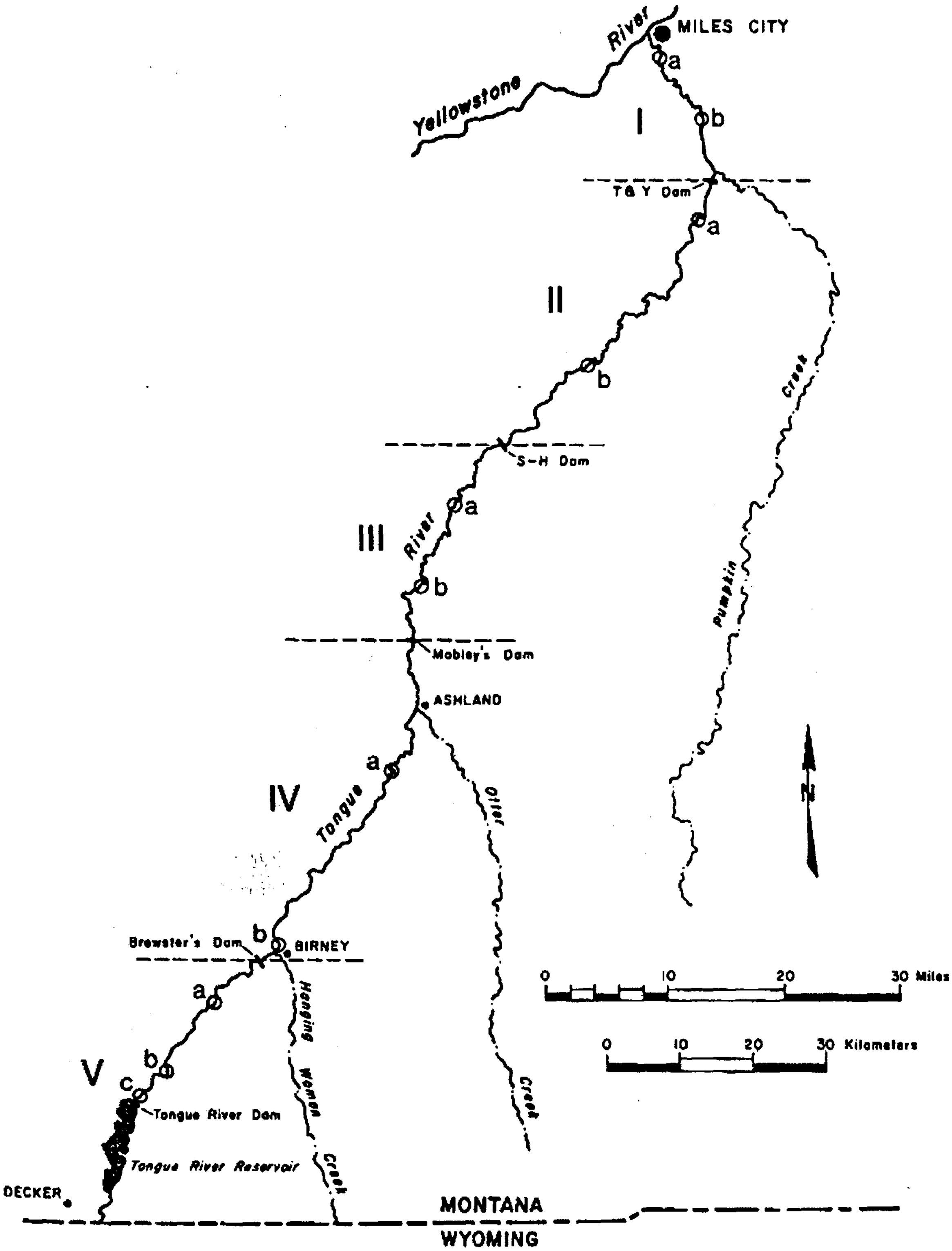

Figure 1 - Map of Tongue River Diversion Dams

SITE HYDRAULICS

The T&Y dam spans the river channel a distance of about 300 ft. The dam is aligned nearly normal to the channel. Observations of low flows over the dam's crest reveal some irregularity in the dam crest elevation across its width. A survey of the left abutment, figure 3 established a crest elevation of 2444.5. For the purposes of this feasibility study, flow conditions over T&Y dam are estimated in Table 1. The thalweg of the river upstream of the dam lies to the right side of the river terminating at the entrance to the diversion canal. Downstream of the dam the river thalweg is less defined. Flows are likely higher along the right bank as alluvial gravel deposits along the left bank form an shallow island at low flows and push flows toward the right bank, Figure 4.

Table 1. Hydraulics of flow over the T&Y Diversion Dam.

Discharge Passing the Dam, ft^3/s	Unit Discharge, per ft of width, $ft^3/s/ft$	Upstream Depth above the Crest, ft (C assumed = 3.0)	Depth of Flow on the Crest (Critical depth), ft
200	0.7	0.4	0.25
600	2.0	0.75	0.50
1000	3.3	1.0	0.67
2500	8.3	2.0	1.33

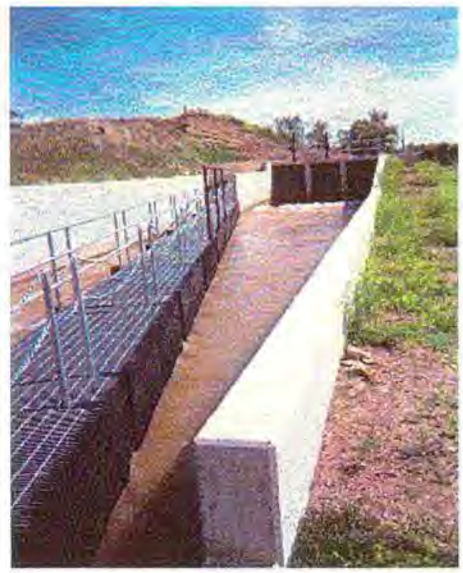

Figure 2 View of T&Y Canal Headworks and Fish Louver

FLOW IN THE LOWER TONGUE RIVER

Flows downstream of T&Y Diversion Dam are largely dependent on releases from Tongue River Reservoir and flow diversion to the T&Y Canal. The T&Y canal diverts up to about 240 ft^3/s for irrigation. The canal operates from mid-March to mid-October. Figure 5 gives the historic average monthly flows in the Tongue River recorded at the USGS gaging station No. 06308500 at the mouth of the Tongue River (12 miles downstream). Highest flows typically occur from May through July and lowest flow during August through October. Historic data gives approximately a 90% probability of 200 ft^3/s or more flow passing the dam during the May through July period each year.

TAILWATER BELOW THE DAM

Tailwater data covering a range of river flows are not available for the area immediately downstream of the dam. The only data available for the concept study was taken during the June 19, 2001 fishway topographic survey of the left bank. The water surface elevation downstream of the dam was recorded as 2433.0. On the same day, the average daily river flow measured at the Tongue River Gaging Station at the mouth of the river was 200 ft^3/s.

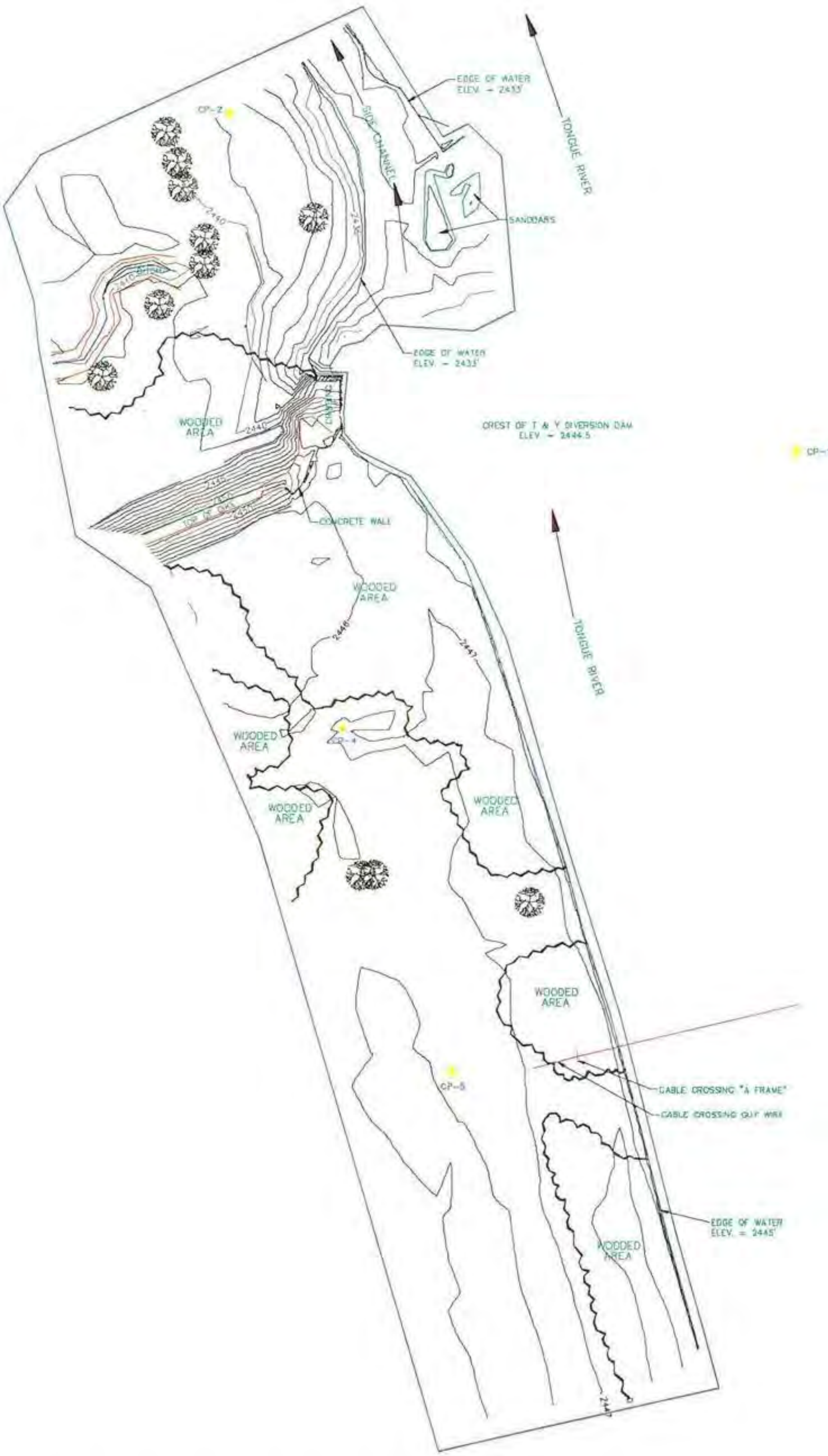

Figure 3 - Survey of area near T&Y Diversion Dam

Figure 4 - View looking upstream at T&Y Diversion Dam, June 19, 2001. River flow downstream of the dam was about 200 ft^3/s.

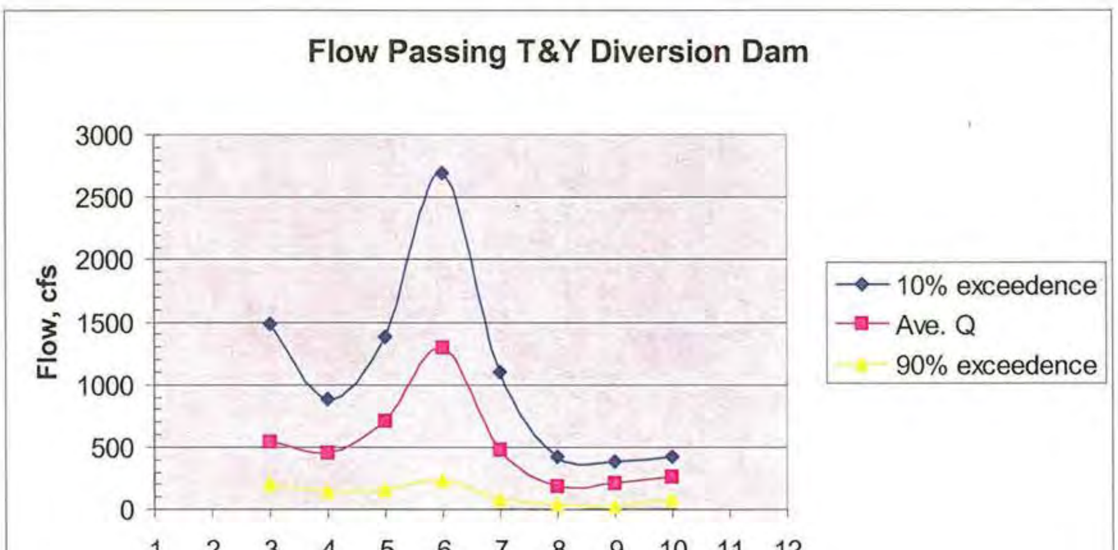

Figure 5 - Historic average-monthly-river flows below T&Y Diversion Dam based on 60 years of record.

FISH PASSAGE REQUIREMENTS AT T&Y DIVERSION DAM

There are numerous types of fish passage structures designed to allow migrating fish species to move both upstream and downstream bypassing dams that otherwise form barriers limiting natural habitat. Most structures that have proven effective specifically target fish species, like salmonids. A fishway must compliment the physical swimming strength and behavioral characteristics of fish it serves. The vast majority of the research and implementation of fish passage structures are focused on passage of salmonids that are strong swimmers. By comparison, the swimming strengths of native species found in the Tongue River are relatively weak.

MAJOR FISH SPECIES OF THE LOWER TONGUE RIVER

Swimming ability and habitat preference of many of the fish species native to the Tongue River were studied by Schmulbach, Tunink, and Zittel,(1982). Swimming performance tests were conducted to determine sustained swimming speed, critical swimming velocity, and short term burst speeds of species endemic to the Missouri River. There are considerable differences within the literature concerning the time duration associated with these definitions. Sustained swimming speed is generally defined as the maximum sustained swimming speed for durations of about 3 hrs. Critical swimming velocity can be though of as the flow velocity at which the fish are carried downstream by the flow. This corresponds to a fish's maximum sustained swimming speed for duration of about 0.1-1.0 hr. Burst speed is typically defined as short term, <15 sec duration, and maximum attainable swimming speed. Table 2 provides swimming performance data for several species of interest on the Tongue River.

Table 2 - Swimming performance estimates for several species found in the Tongue River, Schmulbach et al.

Fish Species	Maturity	Critical Velocity ft/s	Sustained Swimming Speed, ft/s	*Estimated Burst Speed ft/s
Paddlefish	immature	1.9	Unknown	-
Shovelnose Sturgeon	adult	2.5	1.8	5.4
Goldeye	adult	2.6	2.2	6.6
Blue Sucker	adult	2.6	2.3	6.9
Sauger	adult	1.9	1.5	4.5

* Burst speeds are estimated to be 3 times the sustained swimming speed

White and Mefford (2001) conducted flume studies of shovelnose sturgeon swimming ability with respect to flow velocity and bed roughness. Adult shovelnose were found to have burst swimming speeds of about two body lengths per second. Fish moved aggressively through flow velocities of three to four feet per second. Swimming performance was slightly lower over cobble beds verses sand bed channels.

HABITAT PREFERENCES

In addition to swimming capability, understanding habitat preference is also important to determining fishway attraction. Schmulbach, Tunink, and Zittel,(1982) found preferred habitat for the paddlefish, shovelnose sturgeon, and blue suckers are pool areas along main channels where current velocities average about 1.0 ft/sec, roughly half of their sustained swimming speeds. Paddlefish were also frequently found in backwater areas. This data compares with observations made by Hurley (1983), and Tongue River shovelnose sturgeon captures data given by the Yellowstone Impact Study, 1977. The majority of the fish captured were in the main thalweg. Additional insight can be gained by examining the sturgeon's food source habitat. The Yellowstone study found shovelnose sturgeon primarily feed on larval invertebrates in riffles with velocities in the 1 to 2 ft/s range.

The Goldeye and the Sauger show little habitat preference, Schmulbach, Tunink, and Zittel,(1982). They are commonly found in turbid slow moving areas of the main channel, in pools, and backwater.

FISHWAY OPTIONS

Several types of fishways that have been successfully used for passage of non-salmonids were included in the feasibility study. Concepts were developed for a natural style rock channel fishway, a fishway flume with vertical slot style baffles and a fishway flume with denil style baffles. Case studies of non-salmonid fishways using these forms of fish passage follow.

ROCK FISHWAYS

Rock fishways are either constructed channels that bypass a portion of the river flow around a dam or an in-river rock ramp that provides a low gradient path over a dam. Rock fishways are often chosen because they provide good opportunity for multi-specie passage due to the variability of flow conditions across the channel. Rock fishways may be designed as simple prismatic channels of constant bed slope or include features such as meanders, pools and riffles or boulder weirs. As in a natural stream, fishway flow velocity is controlled by stream gradient, bed roughness, channel hydraulic radius, and large scale flow obstructions. These parameters are related in the Manning's Formula for uniform flow in an open channel as;

$$V = \frac{1.49}{n} R^{2/3} S^{1/2} \qquad (1)$$

where: V = average flow velocity, ft/s
n = Manning's coefficient of roughness
R = channel hydraulic radius, ft (ratio of water area to wetted perimeter)
S = slope of the energy grade line

The Manning's coefficient of roughness is a semi-imperial coefficient. Cowan (1956) further describes the coefficient as,

$$n = (n_0 + n_1 + n_2 + n_3 + n_4 + n_5)m_5 \qquad (2)$$

where: n_0 is a function of bed material,
n_1 is a function of channel cross section irregularity,
n_2 is a function of variation in channel cross section,
n_3 is a function of degree of large scale obstructions,
n_4 is a function of aquatic vegetation within the channel and
m_5 is a function of degree of channel meander.

Values for computing n in equation *2* can be found in Chow(1959). For a rock fishway, Manning's n_0 typically is in the range of 0.035 to 0.05.

Equation 1 shows channel flow velocity is a function of channel roughness, channel geometry, and energy slope. For a straight prismatic channel of constant bed roughness and slope, flow velocity varies as a function of the hydraulic radius (area / wetted perimeter) to the $^2/_3$ power. Therefore, a wide shallow channel will convey flow at a lower average velocity than a square shaped channel of similar wetted cross section. Velocity is also a function of the energy slope to the ½ power. Energy slope and channel slope are similar for flow at normal depth. Rock fishway channel slopes typically range from less than 1 percent to 3 percent.

Fishway flow velocity is also be varied by adding attributes that create gradually varied flow conditions (backwater). In gradually varied flow, depth and velocity vary along the channel length resulting in changes in the slope of the energy grade line. Examples of attributes that create gradually varied flow in rock fishways are pools and riffles and boulder weirs.

Through Reclamation's Science and Technology Program the effects of channel hydraulic design parameters have been studied in relation to fish behavior and swimming ability for a number of non-salmonid fish species. These studies have resulted in the design and construction of several rock fishways tailored for the fish communities present. Recent examples of rock fishway designs are listed in Table 3 and described below.

Table 3 - Rock fishways designed for non-salmonid passage

Type	Fishway	Elevation Gain, ft	Fishway Slope Percent	Status
Rock Ramp or Channel	Marble Bluff Dam, Truckee River near Nixon, Nv.	1.5	0.3	Constructed in 1998
Rock Channel with Pool and Riffle	Pyramid Lake Fishway, Experimental Bypass Channel	12	0.58/1.4 0.96/1.6 (pool/riffle)	Constructed in 1996
Rock Channel with Pool and Riffle	Grand Valley Irrigation Company Diversion Dam, Colorado River near Grand Junction, Co.	5	0.9/1.3	Constructed in 1997
Rock Channel with Boulder Weirs	Huntley Diversion Dam, Yellowstone River, Billings, Montana	8	1.8	Constructed in 1999
Rock Channel with Boulder Weirs	Derby Diversion Dam, Truckee River, Reno, Nevada	17	1.6	Constructed in 2002

Examples of Rock Fishways

Pyramid Lake Fishway, Experimental Bypass Channel –

In 1996 FWS and the Nature Conservancy of Northern Nevada with assistance from Reclamation constructed an experimental pool and riffle fishway channel on Pyramid Lake near Reno, Nevada. The rock fishway bypassed an existing poor performing weir and orifice fish ladder, [26]. The meandering channel was constructed to determine if a natural style riffle and pool fishway design could be used to pass cui-ui lake suckers (Chasmistes cujus). Cui-ui are a large benthic oriented sucker species that migrate up the Truckee River to spawn. The test channel was designed to test two different channel slopes. Approximately one-half of the channel length was constructed with an average channel slope of 0.0058 and the other one-half at slope of 0.0096. The channel contained a series of alternating riffle and pool sections. Pools were nearly horizontal and the riffles within the two test sections had slopes of 0.014 and 0.016, respectively. Flow in the pools was 2 to 3 ft deep and about 1 ft deep in the riffle sections. During the testing cui-ui moved steadily up the meandering fishway. Some holding and crowding of fish was observed at the downstream toe of each riffle. The tests proved cui-ui could move through riffles with 4 ft/s mean velocity for distances of at least 30 ft. The tests also demonstrated the importance of flow depth. The relatively shallow flow at the riffle pool interface where fish were holding for short periods subjected the cui-ui to heavy predation by pelicans.

Grand Valley Irrigation Fish Pass –

In 1997, Reclamation constructed an in-stream rock channel fishpass on the Grand Valley Irrigation Company (GVIC) Dam located on the Colorado River near Grand Junction, Colorado, Figure 6. The fishway provides passage over a 5 ft high run-of-river dam for many native and non-native fish found in the Colorado River. The riffle sections are designed for an average velocity of 4 ft/s at a minimum flow and depth of 50 ft^3/s and 1.5 ft, respectively. The design gradients for the fishpass are: riffle slope = 1.3 percent; thalweg slope = 0.7 percent; and channel slope = 0.9 percent. The thalweg slope differs from the channel slope by the sinuosity of the channel. The channel is constructed of riprap laid on a filter fabric. During construction, voids in the riprap were filled with finer material to minimize interstitial flow. The sinuous pattern (meandering channel form) is used to maintain flow depths during low flows. As flow and depth increase the effect of the channel sinuosity on the flow decreases. After three years of operation under a wide range of river flows the riprap fishway channel has remained stable and has blended into the river environment.

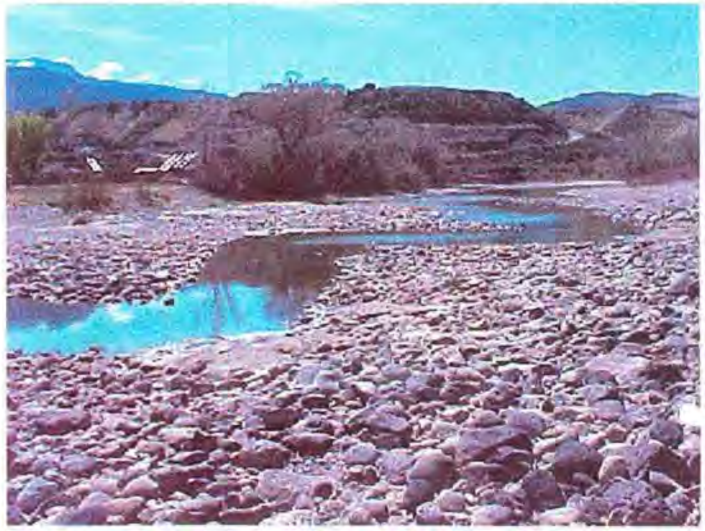

Figure 6 – View of GVIC fishway low flow channel.

Huntley Dam Fishway –

In 1999, Reclamation assisted in the design of a roughened channel fishway for Huntley Dam located on the Yellowstone River downstream of Billings, Montana. The fishway is designed to pass salmonids and many warm water fish species. The fishway, Figure 7, is a riprapped trapezoidal channel on a 1.8 percent grade with boulder arrays spaced every 20 ft. The fishway was constructed in the fall of 1999.

Arial view of Huntley Diversion Dam fishway.

View of Huntley fishway looking upstream.

Figure 7 – Photographs of Huntley Diversion Dam rock channel with boulder weir fishway.

Marble Bluff Gradient Restoration Structure –

In 1998, the river bed elevation below Marble Bluff Dam was raised about 2 ft and stabilized using a rock ramp design, Figure 8. The structure was designed to prevent further channel degradation downstream of the dam and raise the minimum water surface elevation to provide access for fish to a passage facility. The structure was designed based on a 4 ft/s average velocity to ensure fish passage for cui-ui suckers and Lahontan cutthroat trout (Oncorhynchus clarki). Large boulders were added on the north half of the channel to provide additional variability in the flow field. The structure performed well in 1999. An estimated 600,000 cui-ui passed over the structure during the spawning run in 1999 with no apparent delay.

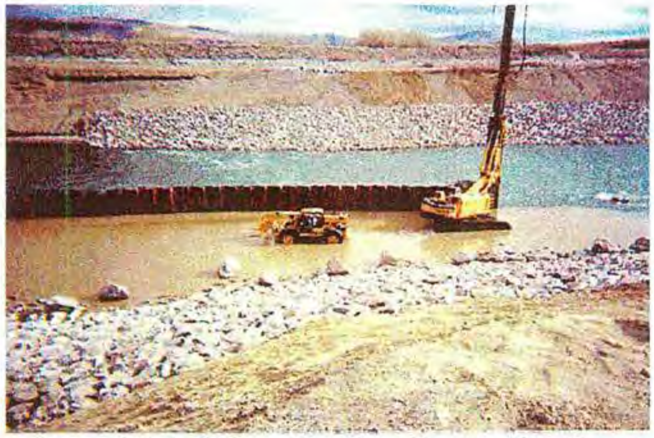

Figure 8 - Construction of Marble Bluff Dam Gradient Restoration Structure

Derby Diversion Dam Fishway –

A rock channel and boulder weir fishway is being constructed at Derby Diversion Dam located on the Truckee River downstream of Reno, Nevada, Figure 9. The fishway is designed to pass cui-ui lake suckers and Lahontan cutthroat trout that are migratory spawners as well as resident fish species. The fishway is about 900 ft long at a slope of 1.8 percent. Boulder weirs are spaced 20 ft apart to create pools will chute flow between boulders. The fishway has a trapezoid shape with a 4 ft wide bottom and 2:1 side slopes. The riprap channel lining will be allowed to naturally silt in. The fishway was constructed in the fall of 2002.

View of rock channel with boulder weirs looking downstream.

View of rock fishway looking upstream.

Figure 9 – Photographs of Derby Diversion Dam rock channel and boulder weir fishway during construction, (2002).

VERTICAL SLOT FISHWAY

A vertical slot fishway uses a series of baffles with vertical slots in each baffle. The baffles are designed to create backwater pools between baffles and higher velocity flow through the baffle slots. The vertical slots allow passage at nearly all depths within the water column and can operate over a relatively large range of flows and river stage. Vertical slot fishways are typically constructed at 3 to 5 percent grade for non-salmonids and 10 percent grade for salmonids.

Examples of Vertical Slot Fishways

Redlands Fishway –

Redlands Fishway is located adjacent to Redlands Diversion Dam on the Gunnison River near Grand Junction, Colorado. The fishway was constructed to assist in the recovery of Colorado pikeminnow (Ptychocheilus lucius) and razorback suckers (Xyrauchen texanus) native to the Colorado River system. The fishway was designed on a 3.75 percent grade with vertical slot baffles spaced every 6 ft, Figure 10. The total elevation difference across the ladder is about 10 ft. The ladder has been operating since 1996. A fish trap is operated at the top of the fishway to monitor fish passage and control upstream passage of some non-native species. Trap results from 1996 through 1998 show between 7,000 and 11,500 native fish including bluehead suckers (Catostomus discobolus), flannel mouth suckers (Catostomus latipinnis), roundtail chub (Gila robusta) and Colorado pikeminnow passed through the fishway each year (Burdick,1999). The predominant fish species passing through the fishway have been bluehead and flannel mouth suckers.

Figure 10 – View of Redlands vertical slot fishway

Pyramid Lake Fishway -

In 1995, Reclamation working with FWS, started investigating fish ladder designs for improving cui-ui passage. A number of ladder baffle designs and gradients were studied using laboratory models and numeric simulations. The design objectives for the project were; hold passage water velocity to about 4.5 ft/s and design baffles that maximize downstream flow within pools between baffles. The objective to maximize downstream flow in fishway pools resulted from field observations that indicated cui-ui tend to school densely and hold for long periods in flow containing large eddies. Holding may be a result of fish disorientation due to poor visibility in turbid water coupled with the complex velocity field within a large eddy. The Pyramid Lake fishway exit ladder was replaced with a unique dual vertical slot baffle design in 1998. The fishway is 8 ft wide, 6 ft deep, with baffles placed every 8 ft of length, figure11. The fishway gradient is 3.1 percent. Dual-slot-chevron shaped baffles were designed to maximize upstream passage attraction between baffles.

Figure 11 – View looking downstream at the Pyramid Lake fishway dual-vertical slot fish ladder.

DENIL FISHWAY

A Denil fishway uses closely spaced baffles to create strong turbulence and rapid energy dissipation to control flow velocity. At a given depth, flow velocity is nearly constant along the chute while varying sharply with depth. Lowest velocities occur near the chute invert. The Denil design requires fish pass by swimming the length of the chute in a single burst. For long ladders, intermediate resting areas are used. Denil fishways are typically set at slopes of 10 to 15 percent.

Example of Denil Fishways

<u>Fairford and Cowan Lake Fishways -</u>

Prototype studies of two Denil ladders on the Fairford River, Manitoba and Cowan Lake, Saskatchewan (Katopodis et al.,1991) found the ladders provided effective passage for sauger, walleys, white suckers, and other resident fish species. The Denil ladders at Fairford and Cowan slope at 12% with run lengths of between 15 and 30 ft, figure 12. The ladders have a total elevation drop of about 7 ft. At Fairford, velocities in the weir chutes varied from about 4.5 ft/s at 0.6 depth to about 2.3 ft/s at 0.2 depth. Slightly higher velocities were measured at Cowan. The velocities are above reported sustained swimming velocities of many species using the ladders. However, velocities were below burst swimming speeds. Weak swimmers were assumed to pass up the Denil ladders by holding close to the bottom in the lowest velocity zone.

Nearly all documented fish using the ladders were adults. Katapodis's study did not compare ladder usage to downstream fish populations. Therefore, the study results do not clearly show the overall effectiveness of the ladders. A previous Canadian study by Schwalme and Mackay (1985), of two Denil ladders and a vertical slot ladder found similar results to Katopodis's. The Schwalme and Mackay study also found juveniles and weaker swimmers appeared to prefer the vertical slot ladder.

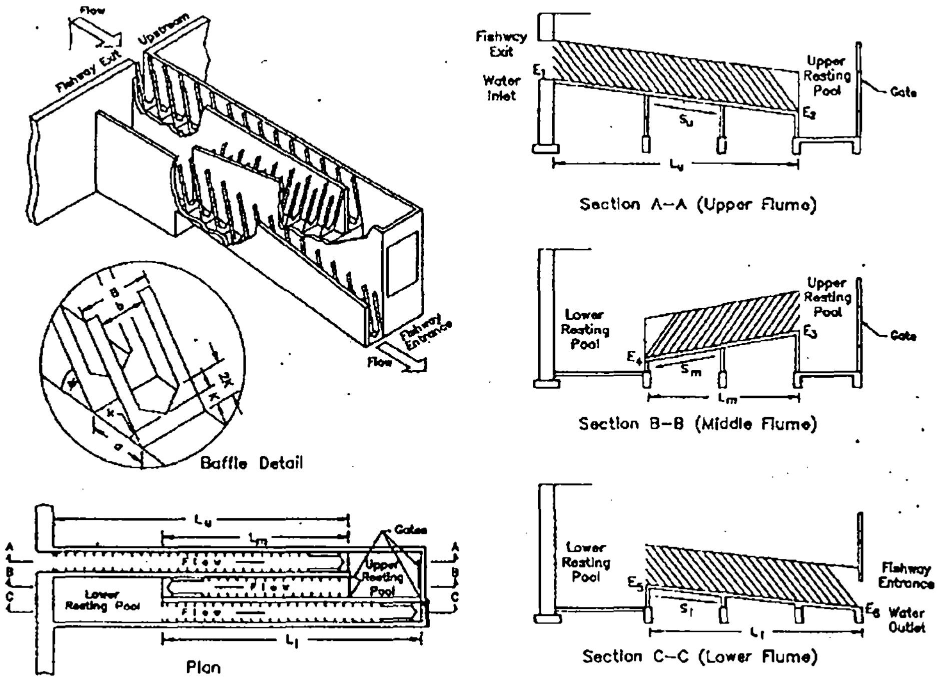

Figure 12 – Fairfield Denil fishway, Katapodis 1991.

T&Y FISHWAY DESIGN CONSIDERATIONS

FISHWAY LOCATION

In the feasibility study, fishway location focused on the left riverbank or dam abutment. Locating a fishway on the right abutment of the dam was not considered due to the close proximity of the canal headworks and fish louver/bypass facilities. Placing a fishway on the dam was also not considered due to the condition of the dam. The concrete shell and timber crib core composition of the dam would make penetrating the dam with a fishway difficult. The dam was probably constructed as a timber crib dam resting on riverbed shales. There is likely no structural foundation or seepage cutoff under the dam. Several large seeps have occurred in recent years under the downstream apron. The irrigation district has been successful in plugging major seeps by placing additional material on the upstream side of the dam.

Three fishway concepts were developed in the study. The alignment of two of the fishway concepts pass around the dam's left abutment and the third would be constructed adjacent to the left abutment-training wall.

FISHWAY ATTRACTION

When ever possible, locating a fishway entrance adjacent to a dam's main flow release structure is preferred. The old saying "go with the flow" is especially true for upstream migrating fish. Studies by Pavlov, (1989) indicates fish move upstream seeking flow at a velocity of between 0.6 and 0.8 times their maximum cruising velocity. If flow velocity is lower than about 0.3 times the fish's cruising speed, fish lose orientation to the flow direction and often hold or drift downstream. White and Mefford (2002) found upstream movement and orientation to the flow was poor for shovelnose sturgeon in flow velocities less than about 1 ft/s. Upstream movement and orientation to the flow were best between in the velocity range of 2 ft/s - 4 ft/s.

SUMMARY OF T&Y FISHWAY HYDRAULIC DESIGN CONDITIONS

The design minimum and maximum conditions listed in Table 4 represent the limits of river flow for which the fishway is designed to operate within the depth and velocity limits prescribed for fish passage. Based on these conditions, T&Y Diversion Dam has a maximum hydraulic height of 11.5 ft that must be provided for by the fishway.

Table 4 - Fishway hydraulic design parameters

Flow Condition	Upstream Water Surface Elevation, ft	Tailwater Elevation, ft	River Flow, ft^3/s
Maximum	~2446.5 (estimated)	~2435.0 (estimated)	2,500.0
Minimum	2444.5 (~ dam crest elev.)	2433.0	200.0

Design objectives for the fishway used for the concept study are based largely on experience with passage of shovelnose sturgeon conducted in the WRRL and experience with passage of other warm water fish species native to western rivers. Options for a T&Y Diversion Dam Fishway were considered that provide for:

- A differential head range between the entrance and exit of about 11.5 ft,
- a minimum fishway depth of 1 ft (low river flows),
- a minimum fishway attraction velocity of 1 ft/s,
- a maximum passage velocity of 4.5 ft/s and
- strong attraction flows to the fishway entrance.

FISHWAY ALTERNATIVES

ALTERNATIVE NO.1 - ROCK CHANNEL FISHWAY

A left bank rock channel and boulder weir fishway is proposed skirting to the west of the diversion dam's abutment, figure 13. The channel would be constructed at a 2.5 percent slope, have a trapezoid shape with a 4 ft bottom width, 2:1 side slopes and a length of 510 feet. The channel would be lined with riprap laid over a geotextile fabric. Thirty sets of boulder weirs would be placed along the channel invert on 15 ft centers. Each boulder weir would pool water upstream creating about a 0.4 ft drop in watersurface through each weir and a maximum passage velocity of 4.5 feet per second. During a minimum design flow of 200 ft^3/s passing over the dam, the fishway would convey about 30 ft^3/s at a depth of 2.4 feet. At a flow of 1,000 ft^3/s passing over the dam, the fishway would convey about 60 ft^3/s at a depth of 3 feet. At the maximum fishway design river flow of 2,500 ft^3/s the fishway would convey 100 ft^3/s to 150 ft^3/s at a depth of about 4 feet.

To the left of the left abutment an earthen dike extends several hundred feet west across the valley. The dike prevents flood flows from passing around the dam's left abutment. The proposed fishway passes through the dike about 80 ft west of the dam abutment. To pass the fishway through the dike, a 6 ft square concrete culvert is proposed laid horizontally. The downstream boulder weir would pool culvert flow. The culvert was sized to be large enough to pass most debris and provide a flow control in the event of a large flood event. Replacing the culvert with an open cut through the dike has been suggested by the resource agencies due to concern on fish response to changes in light inside the culvert. Studies of fish approaching culverts during mid-day hours often show some passage delay due to light conditions. At worst, passage is typically delayed a few hours until the difference in light levels diminishes through the day. Differences in light intensity would be small in the early morning, evening and at night. Antidotal observations of sturgeon reaction to changes in light intensity made by White and Mefford suggest light intensity is not a significant issue for sturgeon passage. This question should be further investigated during final design with the aid of flood hydrology data for the lower Tongue River.

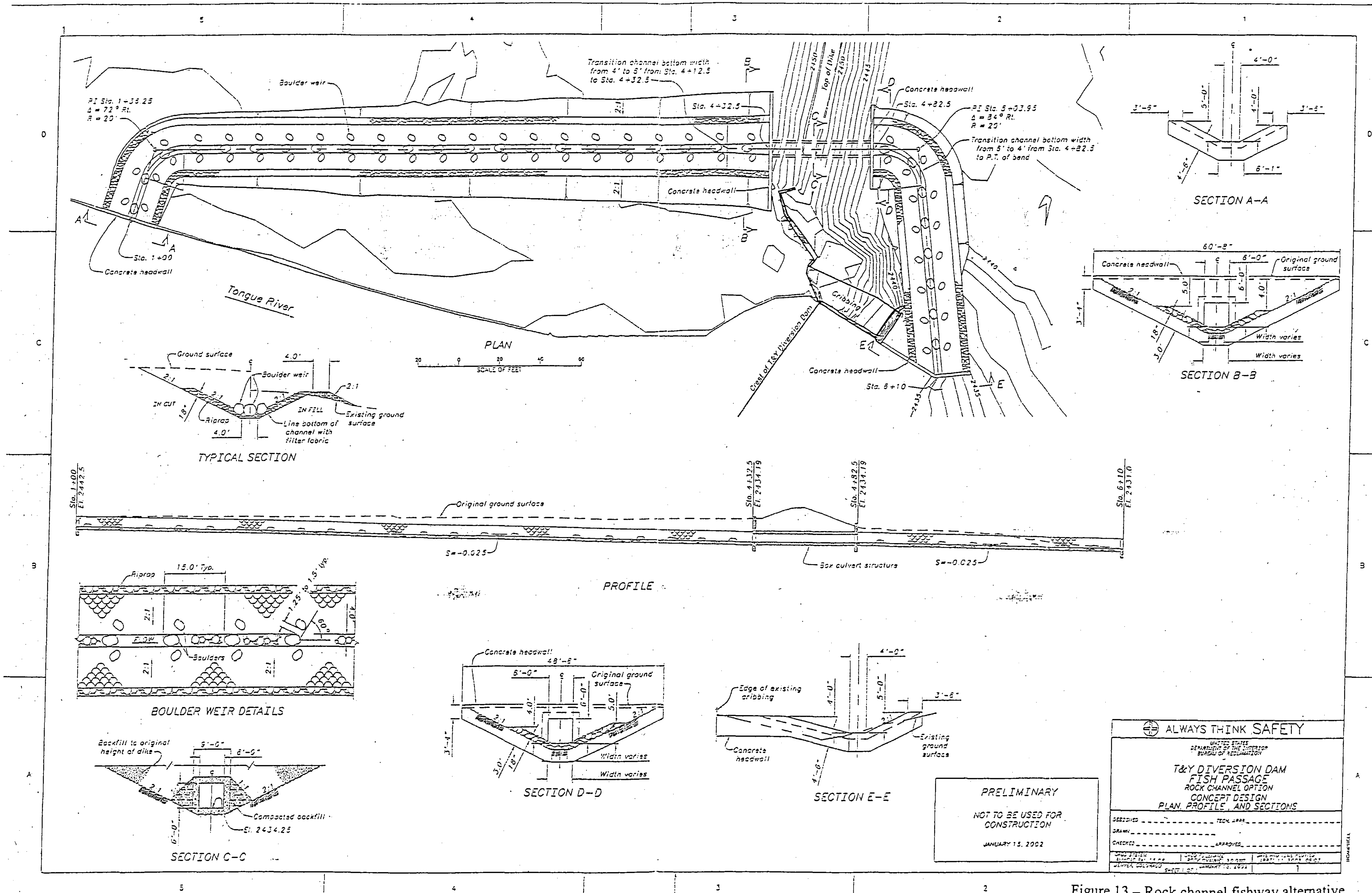

Figure 13 – Rock channel fishway alternative

Rock channel 2D

ALTERNATIVE NO.2 - VERTICAL SLOT FLUME AND BAFFLE FISHWAY

Alternative No. 2 is a concrete flume with vertical slot baffles located adjacent to the left abutment of the dam, figures 14 and 15. The fishway entrance would be located about 65 ft downstream of the dam crest and the fishway exit about 85 ft upstream of the dam crest. The fishway would slope at 5.0 percent with 29, 8-ft-wide by eight-ft-long pools separated by vertical slot baffles. A water surface change of about 0.4 ft would occur across each baffle. The fishway would convey about 30 ft^3/s at a depth of 3 ft for design minimum river stage and 50 ft^3/s at a depth of 5 ft for the design maximum river stage. Table 5 gives a comparison of the proposed T&Y vertical slot alternative to other existing non-salmonid vertical slot fishway ladders.

Table 5 - Vertical Slot Fishway Option, Comparison of proposed fishway hydraulic design to other fishways designed for non-salmonids.

Fishway	Location	Major Fish Species Present	Baffle type	WS drop per baffle, (ft)	Peak velocity across baffle, (ft/s)	Channel slope, (%)
Proposed design	T&Y Diversion Dam	Shovelnose and Pallid Sturgeon, sauger,	Dual Vertical Slot Design	0.4	4.9	5.0
Numana	Truckee River, Nv	Cui-ui sucker and Lahontan Cutthroat Trout	Vertical slot	0.5	5.6	5.0
Pyramid Lake (Exit ladder)	Truckee River, Nv	Cui-ui sucker and Lahontan Cutthroat Trout	Vertical dual slot chevron shape	0.3	4.5	3.1
Redlands	Gunnison River, Co.	Razorback, bluehead and flannel mouth suckers	Vertical slot	0.23	3.8	3.75

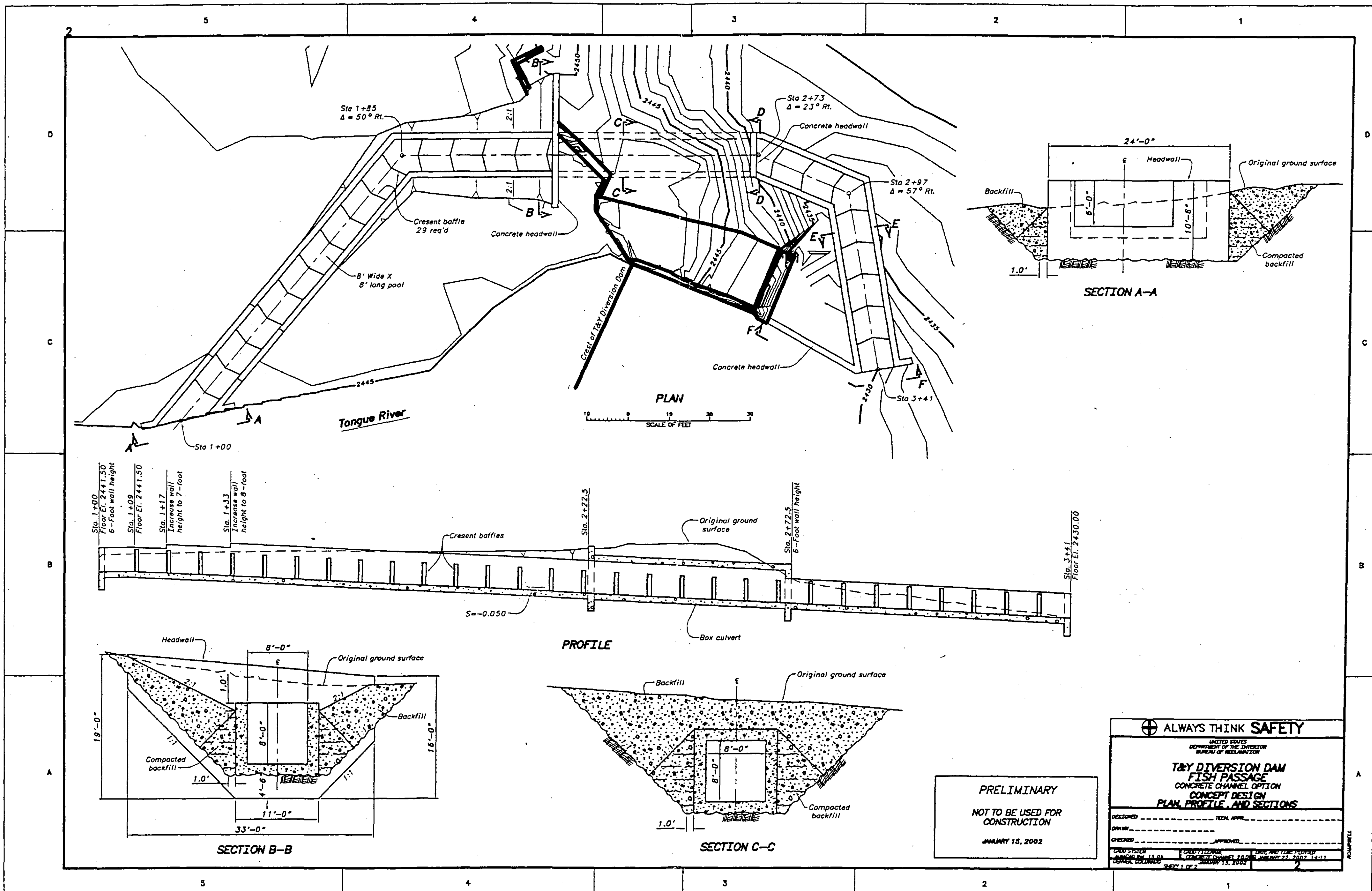

Figure 14 – Vertical slot fishway alternative

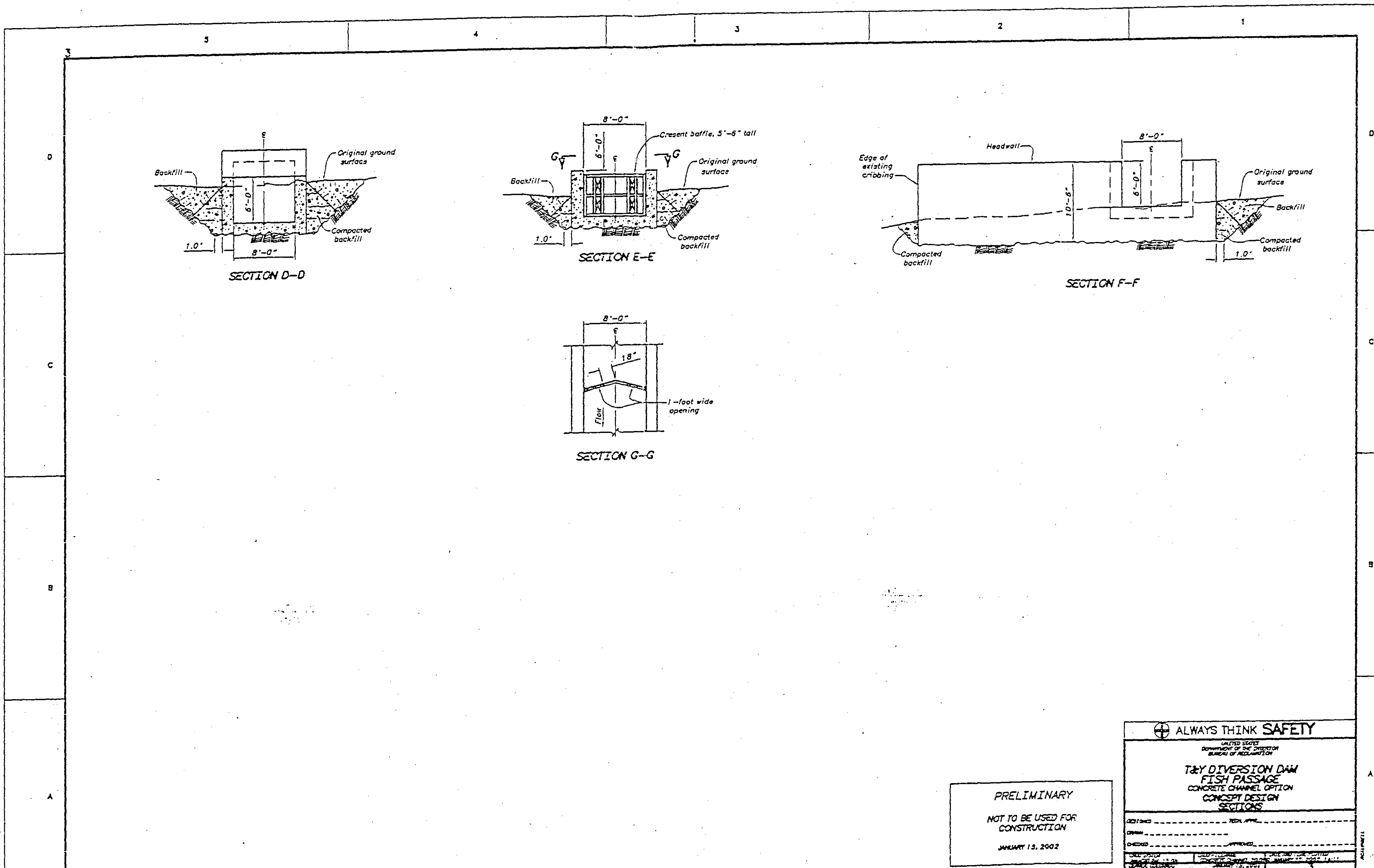

Figure 15 – Vertical slot fishway alternative, sections

ALTERNATIVE NO.3 - DENIL FLUME AND BAFFLE FISHWAY

Alternative three is a denil fishway constructed as part of the left dam abutment, figure 16. The fishway entrance would be located just downstream of the spillway apron on the left bank. The fishway has three runs with denil style baffles joined by two resting pools. The fishway exits approximately 15 ft upstream of the dam crest. A denil fishway requires that fish burst or swim without holding between resting pools. A denil fishway would pass 3 ft^3/s at minimum design river flow and 10 ft^3/s at maximum design river flow. A trashrack would be required at the fishway exit (water entrance) to prevent debris from entering the fishway.

FISHWAY CONSTRUCTION

Several site conditions effect construction of any west bank fishway at T&Y Diversion Dam. First, construction access is currently limited to a private bridge located about a half mile downstream. If the bridge could be used for construction access, an engineering evaluation of the load capacity of the structure would be needed. Some of the area is boggy due to irrigation runoff from the land owner. The landowner has expressed the desire for the project to provide drainage for irrigation return flows should the fishway be constructed. The construction site will require fencing to hold out cattle.

CONSTRUCTION PERIOD

Figure 3 gives monthly historic river flows for the Tongue River below T&Y Diversion Dam. River flow above T&Y Diversion Dam can be as much as 240 ft^3/s higher than the downstream flow records indicate during the irrigation season that runs from mid-April to mid-October. River flow drops in August and remains low into early spring. Temperatures in the area can get extremely cold in December, January and February, Table 6.

Table 6 – Climatic Data for Miles City, Montana

Period of Record Monthly Climate Summary - Period of Record : 1/ 1/1893 to 7/31/1982

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Max. Temperature (F)	27.3	32.2	44.2	59.6	70.5	79.8	89.3	87.0	74.8	61.8	44.6	32.8
Average Min. Temperature (F)	5.7	9.8	21.1	34.1	44.8	53.9	60.0	57.0	46.3	35.1	22.4	12.1
Average Total Precipitation (in.)	0.55	0.43	0.75	1.11	2.00	2.57	1.51	1.13	1.07	0.89	0.56	0.53

CONSTRUCTION COST ESTIMATES

Concept level cost estimates for each fishway alternative are given in tables 7-9. The estimates are based on limited available data of existing structures and site conditions. The estimates do not include costs of environmental permitting, site dewatering, cofferdaming, site access costs or land right-of-way costs. Soils data is not currently available to estimate site dewatering or cofferdaming. However, these items are not thought to be significant. Environmental permitting, site access costs and land right-of-way costs may be significant and should be investigated prior to establishing total project costs. Alternative 1 is $270,000, the estimated cost of Alternative 2 is $710,000 and the estimated cost of Alternative 3 is $200,000.

RECOMMENDED ALTERNATIVE

Fishway Alternative 1 is recommended for T&Y Diversion Dam. Based on studies by White and Mefford the rock channel fishway with boulder weirs provides the best opportunity for sturgeon passage at the dam. Constructing the fishway around the left abutment is preferred to removal of the abutment as required in Alternative 3 due to the unknown condition of the dam abutment interface. The rock fishway design is also less susceptible to debris plugging than the baffled chute designs of Alternatives 2 and 3. The denil fishway is the least expensive and would work well for sager passage, however the design is unproven for sturgeon passage.

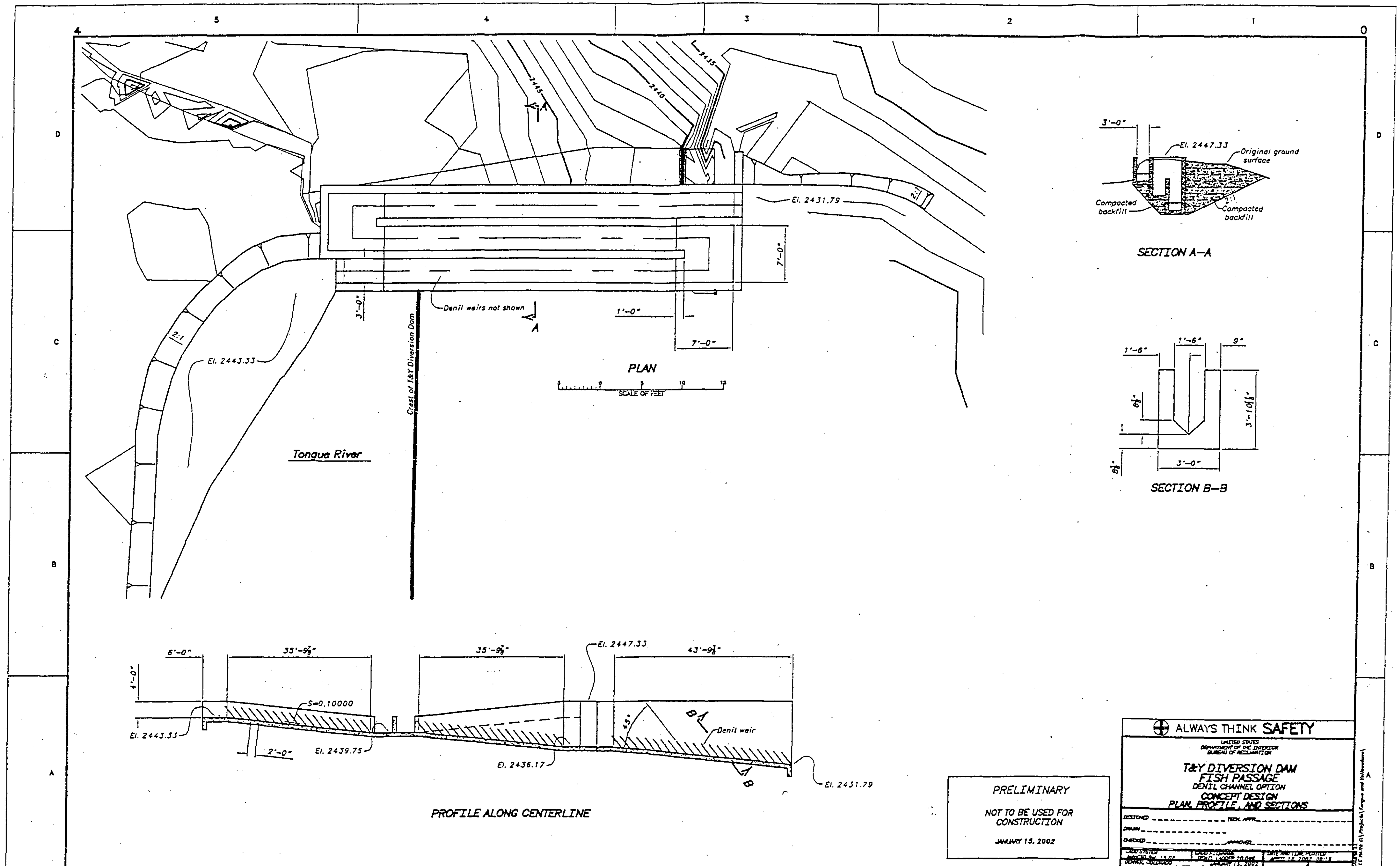

Figure 16 – Denil fishway alternative

Table 7 - Concept level cost estimate for rock channel fishway alternative

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 2 OF 2

FEATURE: Fish Passage Rock Channel (08-May-02)	PROJECT:
	DIVISION:
	FILE: H:\Home\D8170\EST\Spreadsheet\Baumgarten\T&YDiversion Dam.

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Excavation (assume common)		4,460	cy	$10.00	$44,600
	2	Backfill		850	cy	$6.00	$5,100
	3	Compacted Backfill		60	cy	$24.00	$1,440
	4	Reinforced Concrete (Assume commercial plant w/15 mile haul)		145	cy	$500.00	$72,500
	5	Cement		40	tons	$125.00	$5,000
	6	Reinforcement		17,400	lbs	$0.95	$16,530
	7	Riprap (assume commercial source, 20 mile haul)		720	cy	$55.00	$39,600
	8	Geotextile (assume 10 to 16 ounce fabric)		1,610	sy	$4.50	$7,245
		Subtotal					**$192,015**
		Mobilization (5 %)					**$10,000**
		Subtotal					**$202,015**
		Unlisted Items (+/- 10%)					**$17,985**
		Contract Cost					**$220,000**
		Contingencies (+/- 20%)					**$50,000**
		Field Cost					**$270,000**

QUANTITIES		PRICES	
BY Campbell/Mefford	CHECKED	BY R. Baumgarten 5/10/02	CHECKED DCD 5-10-02
DATE PREPARED 04/25/02	APPROVED	DATE 05/08/02	PRICE LEVEL Appraisal 02

Table 8 - Concept level cost estimate for vertical slot fishway alternative

CODE:D-8170 **ESTIMATE WORKSHEET** SHEET 1 OF 1

FEATURE:	PROJECT:
08-May-02 **Fish Passage** **Concrete Channel Option**	**T & Y Diversion Dam**
	DIVISION:
	FILE: H:\Home\D8170\EST\Spreadsheet\Baumgarten\T&YDiversion Dam.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Excavation (assume common)		1,650	cy	$10.00	$16,500
	2	Backfill		1,000	cy	$6.00	$6,000
	3	Compacted Backfill		370	cy	$12.00	$4,440
	4	Reinforced Concrete (Assume commercial plant w/10 mile haul)		430	cy	$450.00	$193,500
	5	Cement		125	tons	$125.00	$15,625
	6	Reinforcement		51,600	lbs	$0.80	$41,280
	7	Cresent Baffles (29 req'd @ 2000 lbs per baffle)		58,000	lbs	$4.00	$232,000
		Subtotal					**$509,345**
		Mobilization (5 %)					**$25,000**
		Subtotal					**$534,345**
		Unlisted Items (+/- 10%)					**$55,655**
		Contract Cost					**$590,000**
		Contingencies (+/- 20%)					**$120,000**
		Field Cost					**$710,000**

QUANTITIES		PRICES	
BY Campbell/Mefford	CHECKED	BY R. Baumgarten 5/10/02	CHECKED RCB 5-10-02
DATE PREPARED 04/25/02	APPROVED	DATE 05/08/02	PRICE LEVEL Appraisal 02

Table 9 – Concept level cost estimate for Denil fishway alternative.

CODE:D-3621 **ESTIMATE WORKSHEET** SHEET 1 OF 1

FEATURE:	10-Sep-02	PROJECT:
FISH PASSAGE DENIL WEIR ALTERNATIVE		T&Y DIVERSION DAM
		DIVISION:
		UNIT:

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	**Civil Works**					
		Channel					
		Concrete		110	cy	$450.00	$49,500
		Reinforcement		16,500	lbs	$0.80	$13,200
		Cement		31	tons	$125.00	$3,875
		Earthwork		400	cy	$10.00	$16,644
		Abutment					
		Wall					
		Concrete		25	cy	$450.00	$11,250
		Reinforcement		3,750	lbs	$0.80	$3,000
		Cement		7	tons	$125.00	$875
	2	**Mechanical**					
		Removable Baffles					
		Steel and gui		11,600	lbs	$3.00	$34,800
		Traskrack and guides		1,200	lbs	$3.00	$3,600
		Mobilization (5 percent of above)					$6,837
		Subtotal					$143,581
		Unlisted items (10 percent)					$14,358
		Subtotal					$157,939
		Contingencies (25 percent)					$39,485
		Total					$198,000

QUANTITIES		PRICES	
BY		BY	CHECKED
DATE PREPARED	APPROVED	DATE	PRICE LEVEL

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